Journal of Forensic and Legal Medicine 19 (2012) 373–380

Contents lists available at SciVerse ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Clinical practice

The application of CamScan 2 in forensic dentistry

Tatjana Dostalova M.D, Ph.D, MBA Professor [a,*], Hana Eliasova Ph.D, Head of Criminalistic Department [b], Michaela Seydlova Ph.D, Associated Professor [a], Jaroslav Broucek Dr. Sc, Member of Criminalistic Department [b], Lenka Vavrickova M.D, Associated Professor [c]

[a] Department of Paediatric Stomatology, 2nd Faculty of Medicine, Charles University in Prague and Faculty Hospital in Motol, V Uvalu 84, 150 06 Prague 5, Czech Republic
[b] Department of Anthropology and Biology, Institute of Criminalistics Prague, Prague, Czech Republic
[c] Department of Stomatology, Charles University in Hradec Kralove, Prague, Czech Republic

ARTICLE INFO

Article history:
Received 20 May 2011
Received in revised form
28 December 2011
Accepted 21 April 2012
Available online 25 May 2012

Keywords:
Forensic science
Anthropology
Dentistry
CamScan 2
Superimposition
DNA

ABSTRACT

Forensic dentistry plays a major role in body identification. The dental examination is very accurate and also, nowadays, in the time of a comprehensive fingerprint and DNA assessment, objectively supported. The identification, which is based on the dental documentation, leads up to 43–89% of a successful process. The purpose of the study is to describe the techniques employed by forensic odontology to identify human remains and also to provide details of some of the novel developments within this area. Comparative methods of dental identification of the unknown subject with pre-mortem clinical records, X-ray images, implant presence, superimposition and DNA analysis confirm the identity of the individual. It was shown that dental identification of a person is based on unique individual characteristics of the dentition and dental restorations, relative resistance of the mineralised dental tissues and dental restorations to changes resulting from decomposition and harsh environmental extremes such as conditions of temperature and violent physical forces.

1. Introduction

The word forensic is powerful, emotive and formidable. It is defined as "pertaining to the law courts" and the word derives from the Latin forensic relating to matters of the 'forum', that is, the judicial courts of Rome. A review into the historical literature reveals many instances of science and medicine being practised for the purposes of enlightenment of the court. Indeed, included in the Capitularies drawn up by the bishops of the first Holy Roman Emperor (Charlemagne) were instructions to include medical expert testimony in cases of wounding, abortion, rape, incest, infanticide and suicide.[1] However, the modern public perception of the essence of the definition has subtly drifted from its original meaning as we tend, quite erroneously, to associate it with the police and investigative authorities rather than its true purpose which is to serve the courts of justice.

Forensic odontology is an integral part of forensic science that is most widely used for identification of living and deceased persons. The dental identification of humans occurs for a number of different reasons, mainly in those cases when the body is fragmentised or disfigured and visual recognition is not possible. Dental identifications have always played a key role in mainly natural and man-made disaster situations and, in particular, in the mass casualties associated with aviation disasters. The identification is essential from both the humanitarian and the religious points of view as well as for judicial reasons.[2]

The earliest recorded case concerns a female associated with Emperor Nero, who was identified after her death through the unique arrangement of her teeth. In the year 66 A.D, Nero's mistress, Sabina, got his wife killed by her soldiers and demanded to see the head of the victim in a dish. She recognised the head by a black anterior tooth. The first modern identification was based on a bridge presence. Dr. Joseph Warren was killed by a bullet that pierced his head in the battle of Bunker Hill (year 1775). His body was buried by the British in a mass grave. A year later, the people of Massachusetts wished to give a proper burial to Dr. Warren, and his body was later identified by Paul Revere by the ivory work which he had done for his friend when alive.[3]

The dental examination is very accurate and also, nowadays, in the time of a comprehensive fingerprint and DNA assessment, objectively supported. The identification, which is based on the dental documentation, leads up to 43–89% of a successful process[4]

* Corresponding author. Tel.: +420 728970059; fax: +420 224433120.
E-mail address: tatjana.dostalova@fnmotol.cz (T. Dostalova).

1752-928X/$ – see front matter © 2012 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.
doi:10.1016/j.jflm.2012.04.015

and it is still a method of choice. The importance of teeth for identification is because of their highly mineralised composition, which makes them resistant to the influences of the external environment. They are not changed by postmortem decomposition and usually withstand to flames, alkalis or even to weak acids.[2,5] One's teeth are also an excellent resource of DNA.[6] Mostly the identification results from a medical treatment and its documentation. The regular dental examination of patients is generally carried out at least once to twice a year, so their dental records represent an important source of identification data. Registration of dental records is mandatory in several European Union (EU) countries; health insurance companies require it and it is performed in dental private clinics as well.

The American Board of Forensic Odontology (ABFO) adopted Guidelines for the Bite Mark Analysis on 21 February 1984. These recommendations were later provided as an obligatory legal norm. The ABFO[7] recommended that the results of the dental identification should be divided into four categories as follows:

1. *Positive identification:* the antemortem and postmortem data match in a sufficient detail, with no unexplainable discrepancies to establish that they are from the same individual.
2. *Possible identification:* the antemortem and postmortem data have consistent features, but because of the quality of either the postmortem remains or the antemortem evidence, it is not possible to establish the identity unambiguously.
3. *Insufficient evidence:* the available information is insufficient to form the basis for a conclusion.
4. *Exclusion:* the antemortem and postmortem data are clearly inconsistent.

Dental examination has several parts:

1. Macrophotography of the oral cavity
2. X-ray examination
3. Intraoral examination

a The number and the type of the teeth and their localisation in the jaws
b A presence of the filling – their material, size and shape
c The root canal treatment
d An occurrence of the fixed (crowns, bridges, etc.) and the removable prosthodontics
e An incorrect tooth eruption (ectopical teeth, unerupted teeth, etc.)
f Any orthodontic anomaly (open bite, cross bite, etc.)
g The fractures of the teeth and jaws play an important role, as well as any infectious focusses or anatomical anomaly such as torus palatinus.

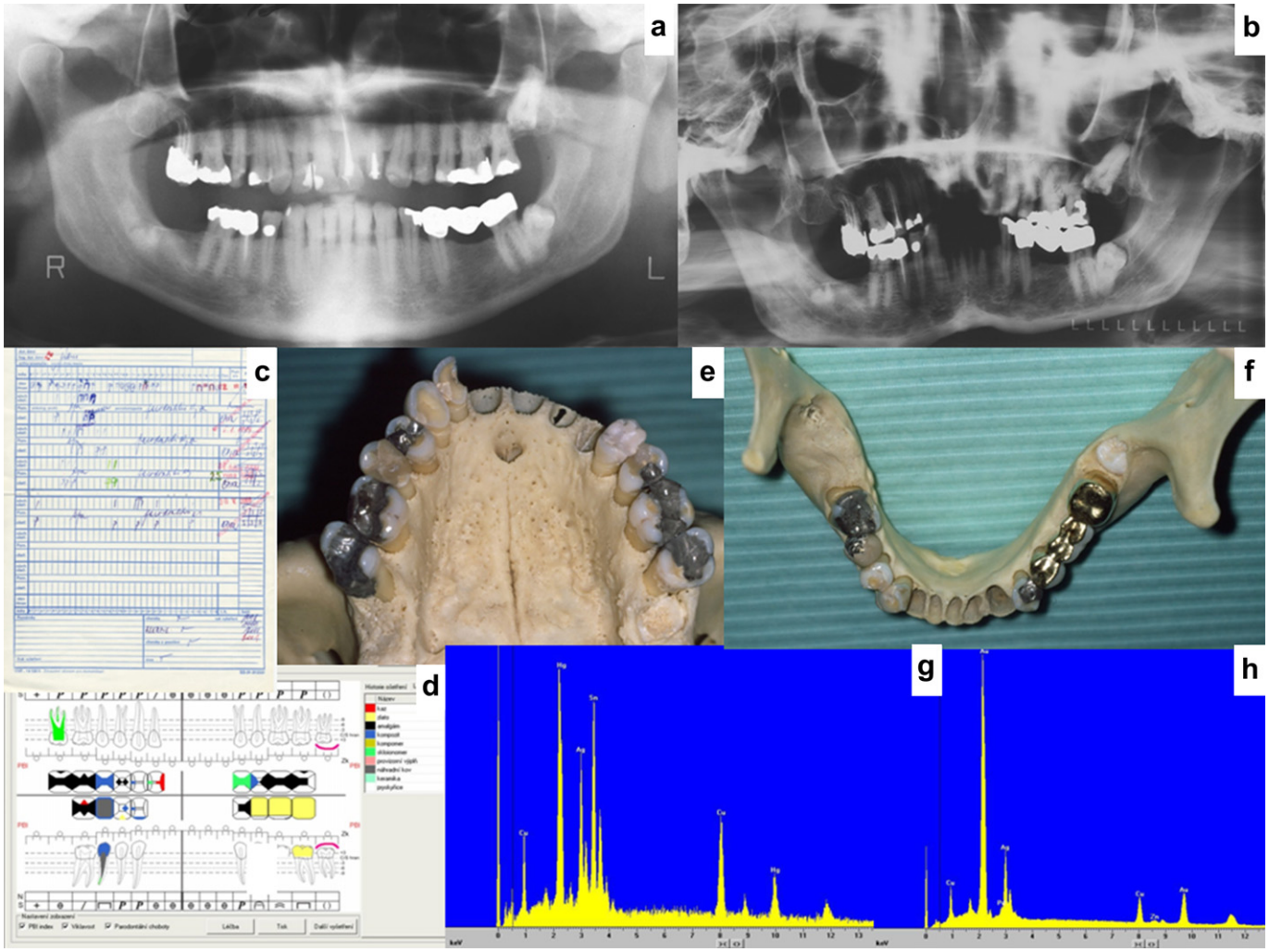

Fig. 1. Comparative method of dental identification: a) antemortem orthopantomogram; b) postmortem orthopantomogram, c) antemortem dental documentation; d) postmortem dental documentation; e) skull – upper jaw; f) skull – lower jaw; f) chemical analysis of filling material, g) chemical analysis of alloy.

h The shape of the teeth, the degree of abrasion and attrition could be an approximate tool to age determination of the victim.

The examination results are recorded into special forms or into the INTERPOL disaster victim identification (DVI) forms (http://www.interpol.int/Public/DisasterVictim/default.asp). An electronic version of this form exists and is called DVI System International.[8]

For many forensic dentists, the identification of found human remains will comprise the majority of their criminalistic work. However, there is rarely a typical dental identification. The resilience of teeth and their supporting tissues to peri- and postmortem assaults provides a wealth of information for those interested in the identity of the deceased. Chemical attack, burning, burial, submersion, and even severe head and neck trauma are all withstood by the dentition to an extent where identification is possible. The lack of a tentative identification or failure to locate dental or similar antemortem records is a more common reason for an odontological investigation to fail.[9]

The purpose of our study is to describe the techniques employed by forensic odontology to identify human remains and also to provide details of some of the novel developments within this area. It was mentioned above that dental structures can provide useful indicators to the individual's identification. The jaws of victims may be exposed and the mandible disarticulated. Using standardised forms and protocols, a dental chart is compiled and a full mouth survey is made using dental X-ray images. Photographs are then taken at various magnifications to record any dental anomalies or unique features. The 'hard' copies of the radiographs, photographs and the dental charting are then reconciled to ensure that no errors have been made in recording the postmortem dental evidence.[10] The dental autopsy is the slowest in the identification process and because of the effect on facial structures it is the last of the investigative procedures.

The forensic dentist produces the postmortem record by careful charting and with written descriptions of the dental structures and radiographs. Once the postmortem record is complete, a comparison between the two records can be carried out. A methodical and systematic comparison is required, examining each tooth and the surrounding structures in turn.[6,11]

2. Comparative method of dental identification

Comparative method of dental identification involves establishment to the highest degree of certainty that the remains of the decedent at the site of mishap or death and details in the antemortem dental records are of the same individual to confirm identity of the individual. Different materials and structures can confirm identification and manifest in the following Fig. 1. The dead body of an unknown man was found by the police in the forest. The missing man was predicted in the police database. Important individual indications were obtained by examining the state of the dentition ante and postmortem. When comparing the antemortem record of the missing person with the orthopantomogram, dental chart and the postmortem findings, we could say that most of the findings corresponded with each other – endodontic therapy – the tooth 17, 45; amalgam fillings; full-veneer bridge from a gold alloy 35, 36, 37. The amalgam fillings were found on several teeth. The analysis of the fillings and yellow pontic alloy was implemented to know its composition and therefore the probable producer. The CamScan 2 scanning electron microscope linked with

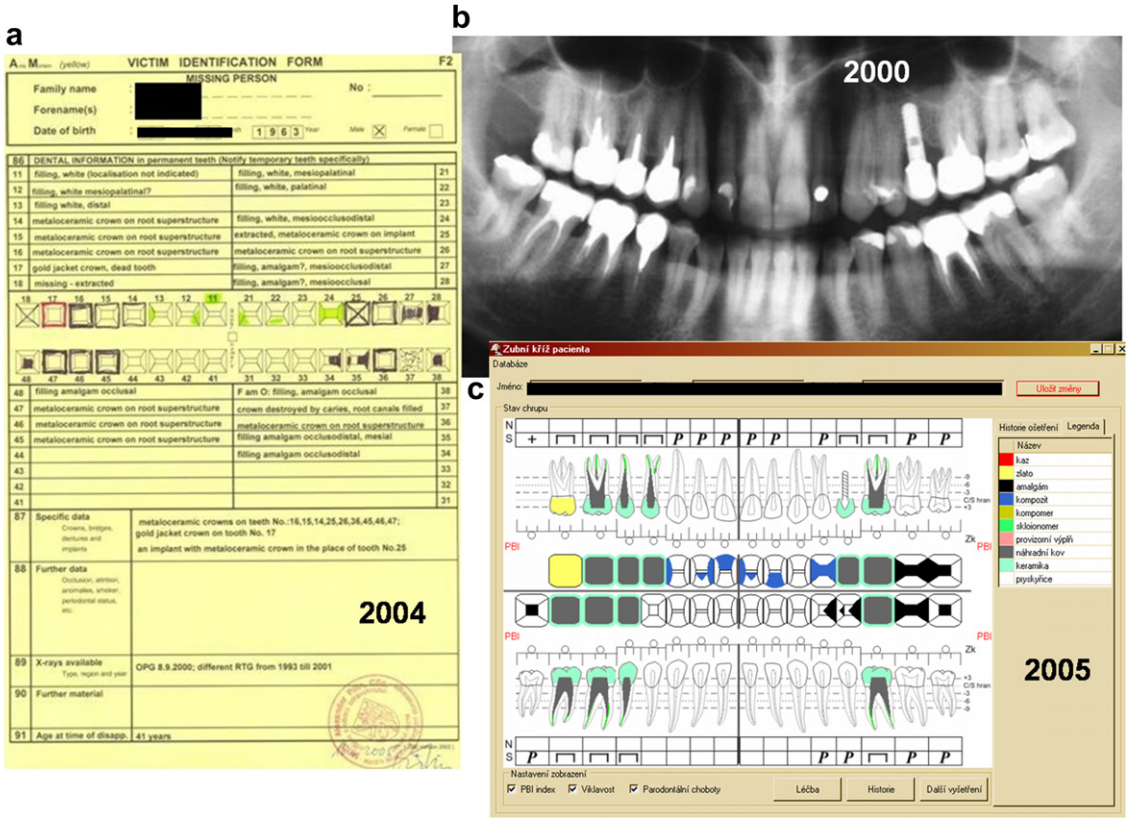

Fig. 2. Implant identification: a) yellow DVI Form; b) antemortem orthopantomogram; c) antemortem dental documentation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

a microanalysator of characteristic X-radiation – EDAX 9900 was used. The amalgam SAFARGAM and noble alloy Aurix (Safina, Prague) were analysed in an analogous way as the comparative material. Performed analyses confirmed that the filling material and yellow alloy of the bridge have an analogous composition like the Safargam and Aurix material, the Czech production. Nevertheless, because of homogeneity of material, the proportion of single elements in the samples – gold, silver, pewter and copper, varied and precise quantitative could not be done. Even the composition of material is a trade secret, the established absence of zinc in the analysed amalgam led to the presumption that the amalgam is SAFARGAM being produced by the SAFINA Company. The analyses confirmed unerupted teeth 28, 38.

3. Implant

A new element for identification is the dental implant presence as was used in the mass disaster victim Tsunami (2004) identification. A man was assessed in the place of the disaster by experts, who recorded their findings into the DVI forms concerning the dental aspect of the examination (Fig. 2). The man had the orthopantomogram from the year 2000. The presence of the implant in the region 25 was in the free text with specific data. The differences between the stages of the found teeth and the orthopantomogram findings from the year 2000 were in the treatment of the teeth 17 and 22. The tooth 17 was provided with a full veneer crown from a golden alloy and the palatal amalgam filling in the tooth 22 was changed. During 3–4 years, treatments were made but the findings were not in contradiction with the identification.

4. X-ray image

During house demolishing, human remains were found. The determination of the postmortem interval was very problematic. The body was dismembered for the purpose of covert disposal. The method included separation of body parts with an electric saw. After decapitation and separation of upper extremities and the trunk, the pelvis and parts of lower extremities were boiled vigorously for several hours with a detergent added to the solution. The radiographic study of all recovered body parts revealed no evidence of remote or recent skeletal trauma. Visual and radiographic studies of dentition were realised. A presumed person, a man, aged 45, who disappeared from his family a quarter of a year before, was found on searching for missing persons. All recovered body parts were consistent with the missing person's known physical characteristics, carried out by the anthropology analysis. Postmortem radiographic studies of dentition were successful after searching antemortem dental X-rays. The features on the X-rays of the dead body answered to the findings on the X-rays of the first missing man (Fig. 3).

5. Chemical analysis of dental fillings

On finding the human remnants' unknown identity, forensic anthropologists screen skeletal remnants with morphoscopic and metric investigation, which is focussed on the determination of ethnic affinity, sex, height of stature, age and individual characteristics.

The dental documentation contains investigations which often do not accept the identification, as same as do not confirm. Because

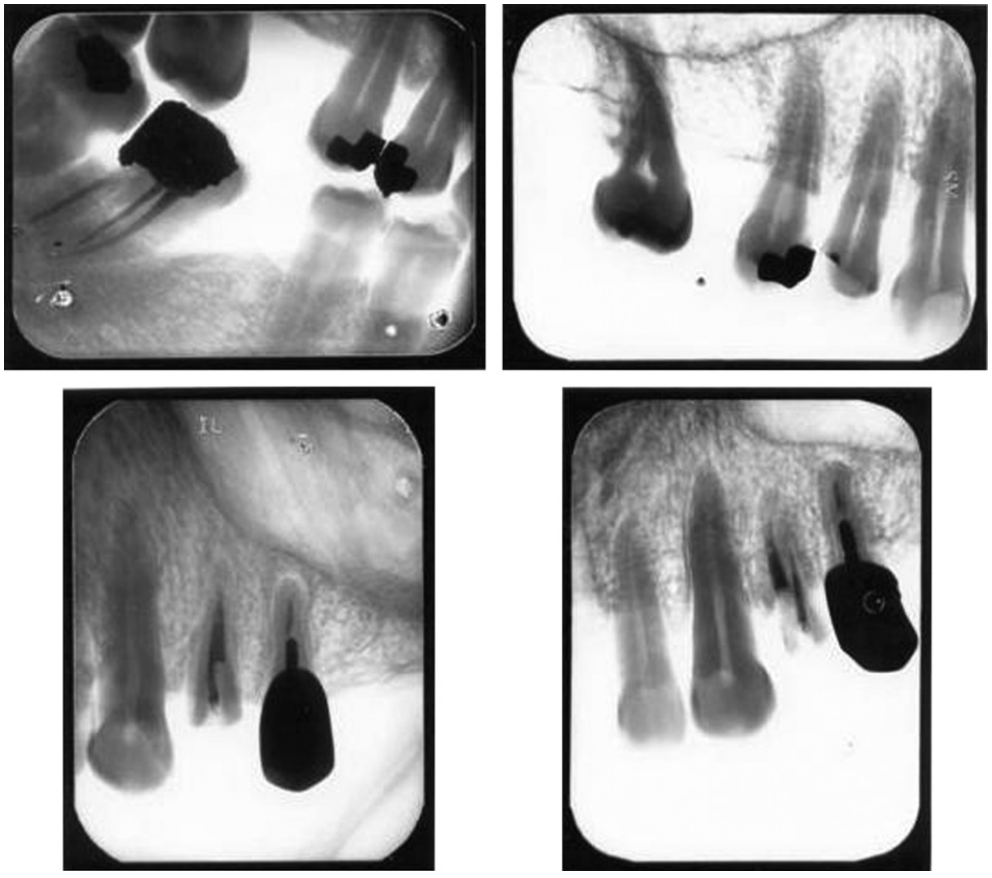

Fig. 3. Ante and postmortem X-ray image analysis.

of that it is necessary to supply these findings with other methods, that is, the superimposition which consists of the unknown corpse skull projection onto the portrait photograph of the selected person. The presumption for exact evaluation of the superprojection adjusting is the conformity between the skull perspective and the portrait perspective. The signs important for anthropological comparison of the skull with the portrait are physically highlighted on the skull, for example, orbit margins, aperture piriformis nasi shape, soft tissue depth in important craniometric points, etc.

The skull is placed on the craniofor and scanned with a camera. The portrait placed on the desk is scanned with a vertically situated second camera. The superprojection process has a shape of additive composition of the skull images and portraits on the monitor in size in life. By the help of the mixing desk, it is possible to change the character of the superprojection image, for example, colour intensity regulation, divide the image area in the sections with different representation of both components, eventually with absence of one of them. After the finding of the final perspective, video sequences are created for anthropological comparison needs, which allow analysis of the continuous (soft interface) or jump conversions between both components in the marked anatomic attributes.

The superprojection images are subsequently evaluated, if all morphological and metrical marks, including different individual anomalies on the skull, are responding adequately to the marks on the chosen person's portrait (the craniofacial analysis and synthesis method).

We are presenting the forensic documentation and superprojection images in the following case report (Fig. 4), when a corpse in the advanced stage of decay was found. The police investigation obtained findings implying that it could be the corpse of the missing person. All dates realised with complex medicojudical and anthropological investigation sustained hypothesis that it was the chosen relevant missing person. Postmortem interval was estimated according to taphonomic changes (from Greek taphos = funeral) of the soft tissues maximum for the period of half a year. Nevertheless, on the basis of presented dates, the dead man could not be unambiguously identified. Therefore, it was necessary to find some individual identification marks. Important identification marks offered dead man's dentition. The examination discovered that 22 teeth showed larger or smaller dental interventions or presence of untreated caries. The samples of the bright fillings were taken from the teeth 14, 15, 16, 17, 24, 27, 28, 35, 36, 37, 38 and 47. Chemical analysis found that all taken samples were made of the same material. According to the chemical composition of samples (Si, Al, P, Zn, K, Ca and Na), it could probably be glass-ionomer cement. The material analysis of fixed crown alloys 22, 23, 25, 26 and veneers of teeth 22 and 25 was made by method SEM/EDX on the scanning microscope CamScan 2D in connection with electron microanalysator Link ISIS Series 300. Presence of chemical elements – chromium (Cr), ferrum (Fe), nickel (Ni) and manganese (Mn) was approved which originated from crown alloys and chemical elements – titanium (Ti), nitrogen (N) – crowns were plated with titanium nitride alloy (TiN_2) (Fig. 4). Titanium nitride colour is yellow eventually yellowed, so it reminds gold. The

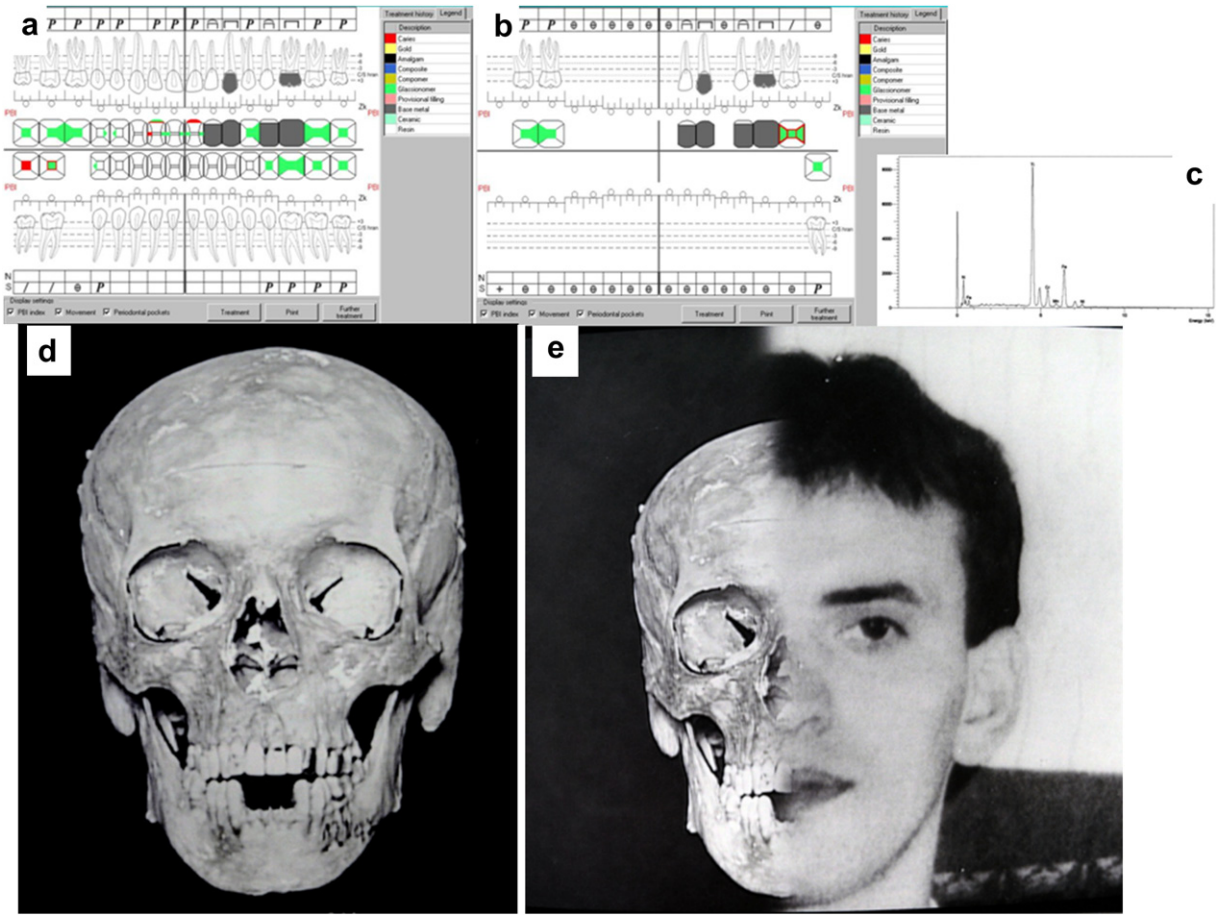

Fig. 4. Photographic Superimposition: a) postmortem orthopantomogram, b) antemortem dental documentation; c) chemical analysis of alloy. d) skull; e) superimposition.

detection of the teeth veneers 22 and 25 identified, that it is plastic (polymethylmetacrylate). The copy of the antemortem dental documentation was not complete. The conformity was found. Superprojection skull setting in the missing person portrait proved the parameter correspondence between skull and head of the missing person (horizontal and vertical proportions of the face, thickness of the soft tissues in defined anthropometric points, position and size of the eyes in orbits, nose morphology and apertura nasi piriformis nasi shape, correspondence of the mouth width and position of the mouth and teeth line, chin shape and mandible contour, etc.)

6. Role of DNA in dental identifications

Because of the resistant nature of dental tissues to environmental assaults, such as incineration, immersion, trauma, mutilation and decomposition, teeth represent an excellent source of DNA material.[12] When conventional dental identification methods fail, this biological material can provide the necessary link to prove identity.[13] With the advent of the polymerase chain reaction (PCR), a technique that allows amplification of DNA at pre-selected, specific sites, this source of evidence is becoming increasingly popular with investigators. Comparison of DNA preserved in and extracted from the teeth of an unidentified individual can be made to a known antemortem sample (stored blood, hairbrush, clothing, cervical smear, biopsy, etc.) or to a parent or sibling.[6]

The dead body of an unknown man was found by the police in the forest. Decomposed changes of soft tissues indicated that the death had come approximately 5 years ago. The remains were skeletonised and sent to the Institute of Criminalistics Prague for the anthropological examination. The skeleton was complete. The sexually dimorphic features of the skull and especially the pelvis identified unambiguously the male sex. The classification of the skeletal age includes the examination of the transformation of the pubic joint surfaces and internal structures of humeral and femoral epiphyses. The analysis of the teeth has been intended on the detailed evaluation of dental age and on the basis of changes of hard tissues visible on sagittal cuts of frontal teeth. The following characteristics were evaluated: attrition, secondary dentine, secondary cement, resorption of secondary cement and transparency of radical dentine. The individual's age was estimated at 50 ± 5 years (Fig. 5). Important individual indications were obtained by examining the state of the dentition. The alveolar bone was markedly resorbed. Two open alveoli in maxilla indicated that the teeth fell out postmortem. Signs of abrasions were observed on the necks of some teeth. Filling of teeth was seen in upper and lower dental arches. The analysis of the metal bridge in the upper jaw was implemented by means of the CamScan 2 scanning electron microscope linked with a microanalysator of characteristic X-radiation – EDAX 9900 and showed non-noble alloy with yellow plating (TiN_2) typical of Russian dentistry. Metal ceramic crowns loco 45, 46 and 35, 37 were observed, there were posts in the root channels. A presumed person, a Russian man, aged 50, who disappeared from a hotel, was predicted. The dental record from Russia was not retrievable.

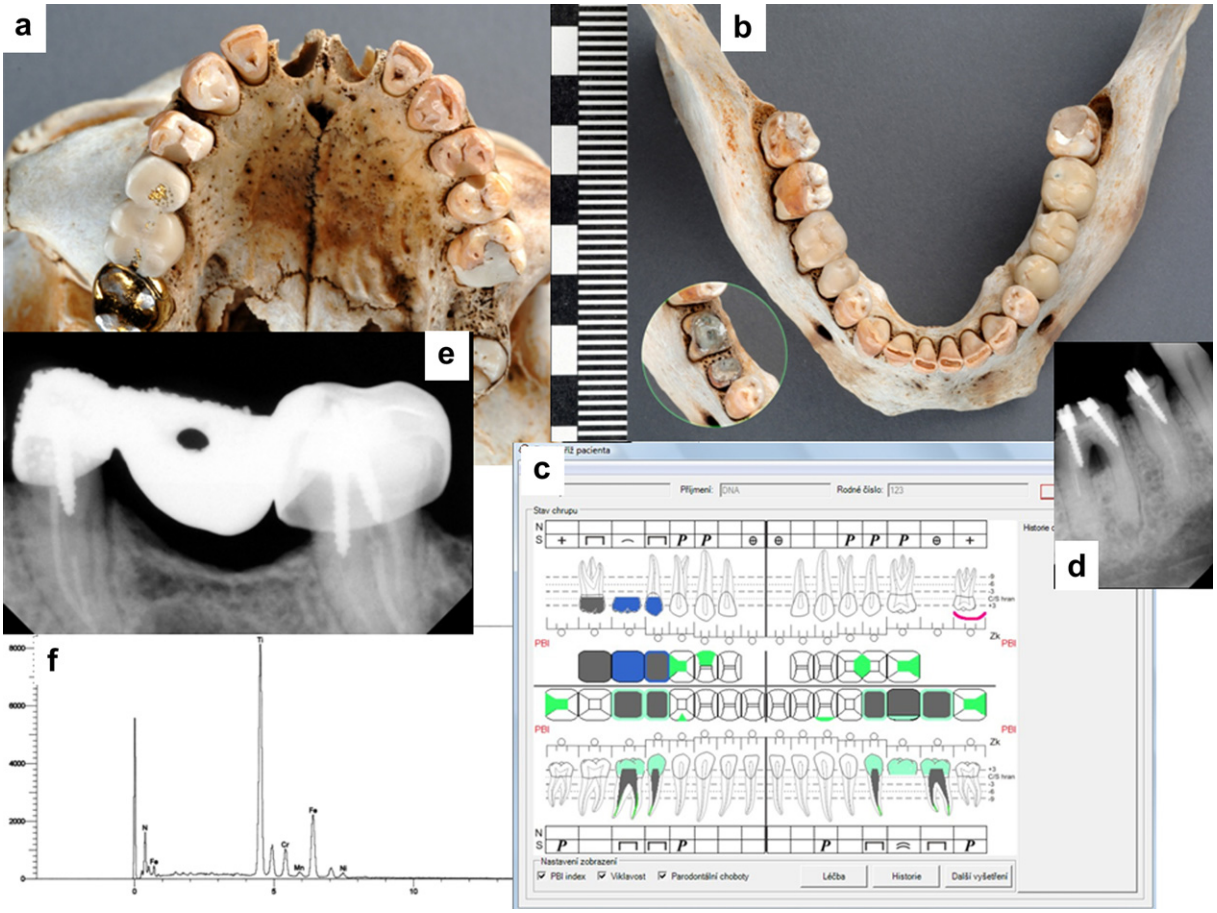

Fig. 5. Dental postmortem documentation: a) skull – upper jaw; b) skull – lower jaw; c) postmortem dental documentation; d) X-ray image of dental bridge loco 35-37; e) X-ray image of endodontic therapy and posts loco 45, 46; f) chemical analysis of alloy. loco 15, 17.

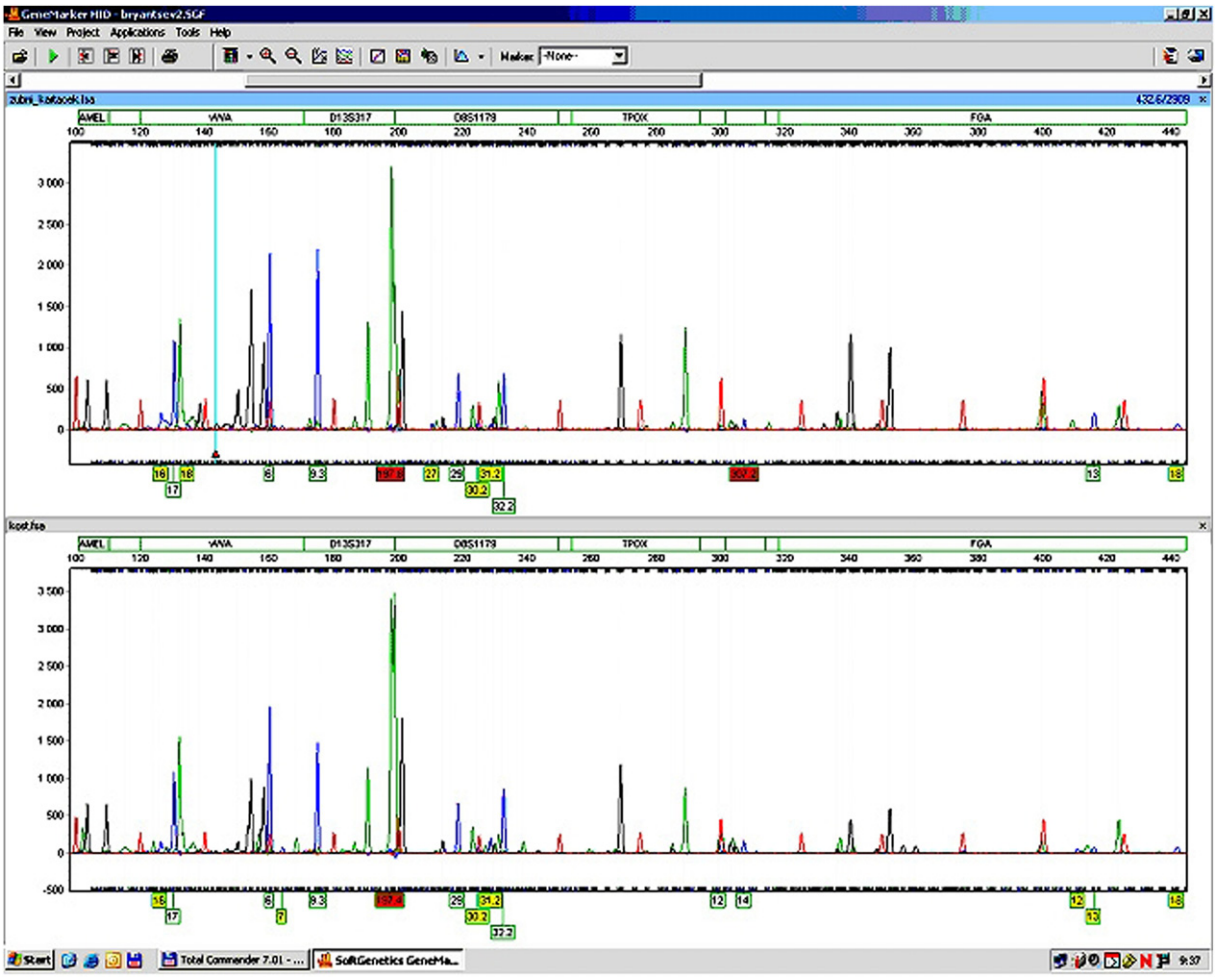

Fig. 6. DNA analysis ante and postmortem.

Comparison of DNA preserved in and extracted from the teeth of an unidentified individual was made from the antemortem sample – hairbrush and tooth brush (Fig. 6) and confirmed the identification.

7. Conclusion

Whenever a human body or the remains of a human body are found, the police are called for further investigation. A tentative identification is possible by considering the geographical location where the body was found, the physical features, the available wallet or driving license or any other personal belonging of the deceased individual. Dental identification of an individual can be made mainly by two methods, namely, comparative method of dental identification and postmortem dental profiling.[6,14,15] When antemortem dental records are unavailable and other methods of identification are not possible, the forensic dentist can assist in limiting the population pool to which the deceased is likely to belong and thus increase the likelihood of locating antemortem dental records. This process is known as postmortem dental profiling. It was discussed that the information from this process will enable a more focussed search for antemortem records. A postmortem dental profile will typically provide information on the deceased's age, ancestry background, sex and socio-economic status. In some instances, it is possible to provide additional information. It was shown that dental identification of a person is based on unique individual characteristics of the dentition and dental restorations, relative resistance of the mineralised dental tissues and dental restorations to changes resulting from decomposition and harsh environmental extremes such as conditions of temperature and violent physical forces.[16]

Ethical approval

None declared.

Funding

This project has been supported by the grant No. NT 13351-4 MZCR and project VF 20102014007.

Conflict of interest

None.

Acknowledgements

None.

References

1. Payne-James J, Busuttil A. History and development of forensic medicine and pathology. In: Payne-James J, Busutt Al, Smock W, editors. *Forensic medicine, clinical and pathological aspects*. Greenwich Medical Media; 2003. p. 3–12.

2. Valenzuela A, Marques T, Exposito N, Martín-De Las Heras S, García G. Comparative study of efficiency of dental methods for identification of burn victims in two bus accidents in Spain. *Am J Forensic Med Pathol* 2002;**23**:390–3.
3. Chandra Shekar BR, Reddy CV. Role of dentist in person identification. *Indian J Dent Res* 2009;**20**:356–60 [Review].
4. Griffiths C, Hilton J, Lain R. Aspects of forensic responses to the Bali bombings. *ADF Health* 2003;**4**:50–5.
5. Jones DG. Odontology often is final piece to grim puzzle. *J Calif Dent Assoc* 1998;**26**:650–65.
6. Sweet D, DiZinno JA. Personal identification through dental evidence-tooth fragments to DNA. *J Calif Dent Assoc* 1996;**24**:35–42.
7. American Board of Forensic Odontology. Body identification guidelines. *J Am Dent Assoc* 1998;**125**(X):1244–54.
8. PLASS DATA. DVI System International – Disaster Victim Identification. www.dvisystem.com [accessed 11.12.06].
9. Pretty IA. Forensic dentistry: 1. Identification of human remains. *Dent Update* 2007;**34**:621–2. 624-6, 629-30.
10. Hampson GV, Cook SP, Frederiksen SR. The Australian defence force response to the Bali bombing, 12 October, 2002. *Med J Aust* 2002;**177**:620–3.
11. Goldstein M, Sweet DJ, Wood RE. A specimen positioning device for dental radiographic identification. Image geometry considerations. *J Forensic Sci* 1998;**43**:185–9.
12. Schwartz TR, Schwartz EA, Mieszerski L, McNally L, Kobilinsky L. Characterization of deoxyribonucleic acid (DNA) obtained from teeth subjected to various environmental conditions. *J Forensic Sci* 1991;**36**:979–90.
13. Sweet D, Hildebrand D. Recovery of DNA from human teeth by cryogenic grinding. *J Forensic Sci* 1998;**43**:1199–202.
14. Manjunath BC, Chandrashekar BR, Mahesh M, Vatchala Rani RM. DNA Profiling and forensic dentistry – a review of the recent concepts and trends. *J Forensic Leg Med* 2011;**18**:191–7.
15. Bruce-Chwatt RM. A brief history of Forensic odontology since 1775. *J Forensic Leg Med* 2010;**17**:127–30.
16. Pretty IA, Webb DA, Sweet D. The design and assessment of mock mass disasters for dental personnel. *J Forensic Sci* 2001;**46**:74–9.